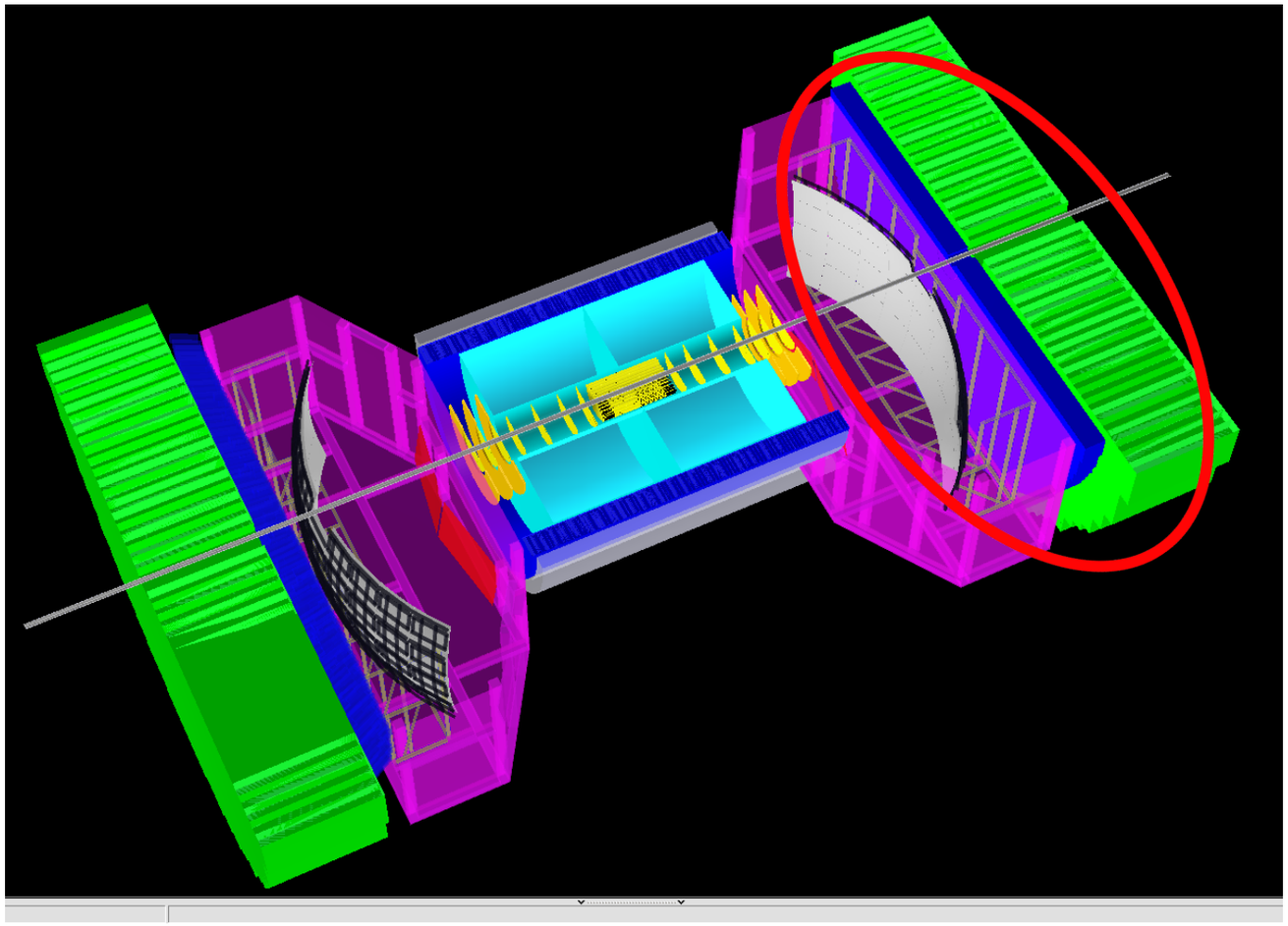
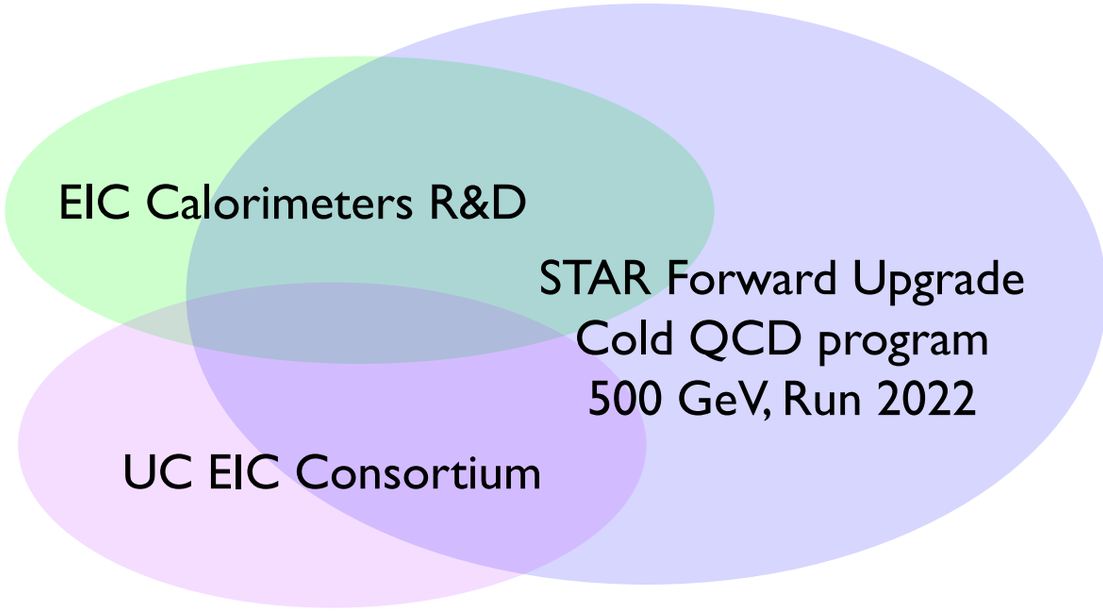
eRD1, HCal Report.

O.Tsai (UCLA)

Jan. 30, 2020 EIC R&D Meeting, BNL.

We will continue to concentrate efforts on optimization of Hadron EndCap.
Moving toward targeted R&D.





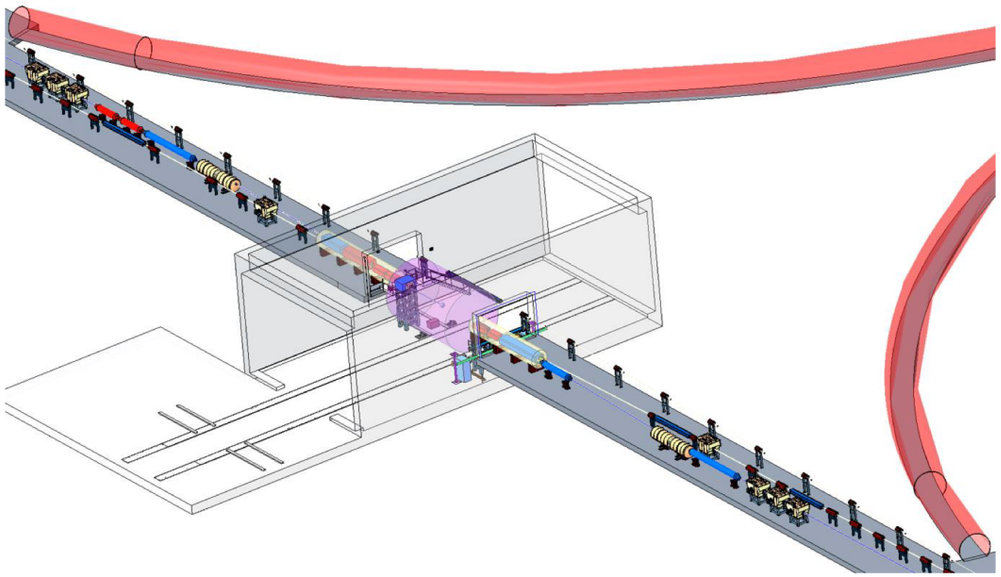
- People
- Similar desired system performance
- Observables
- Technical Challenges

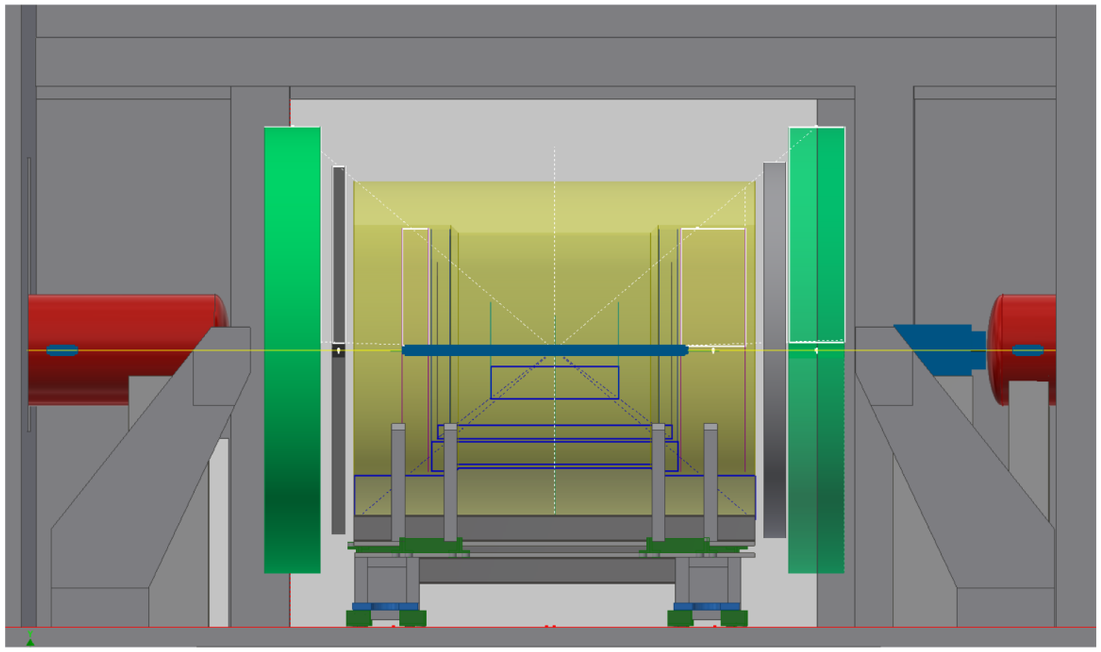
Possible implementations for central detector:

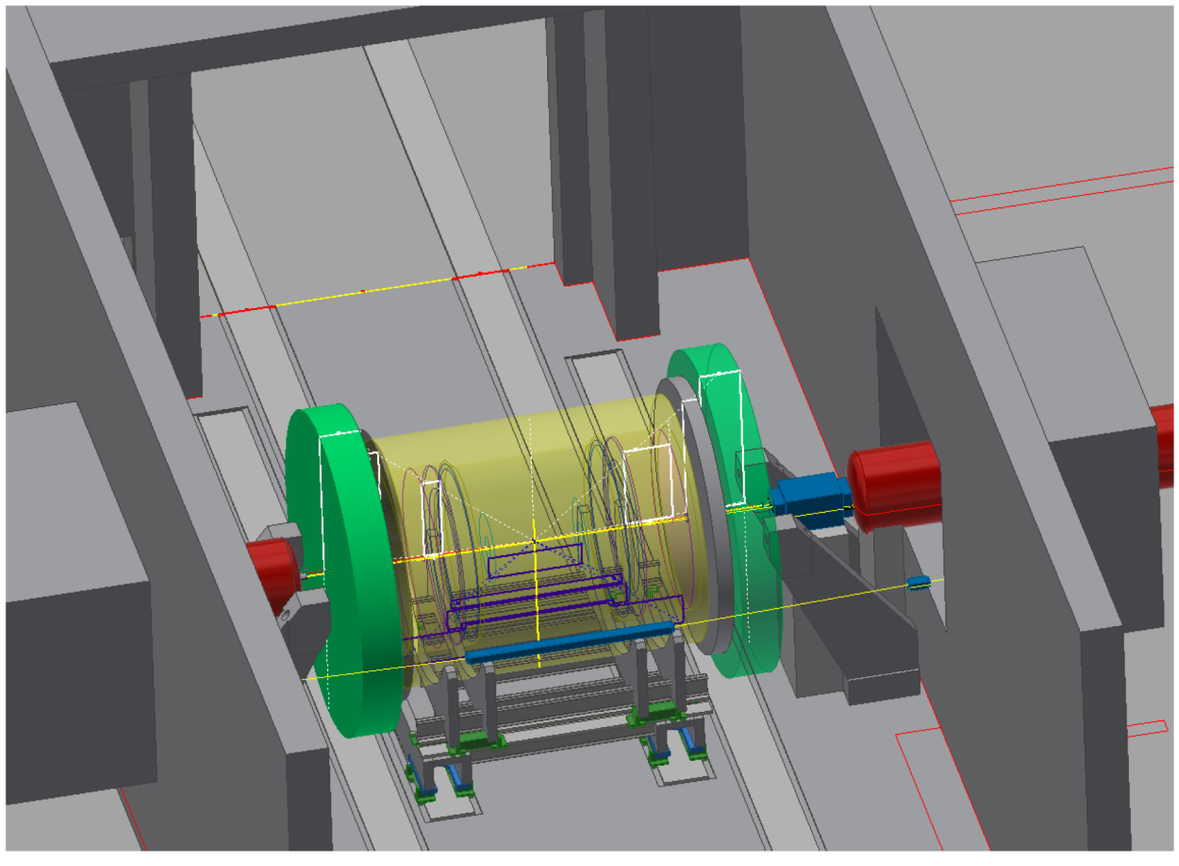
- Shashlyk + Fe/Sc (STAR 2022)
- Shashlyk + Fe/Sc (finer sampling) – optimization via MC (Z. Xu/M.Sergeeva)
- W/ScFi + Pb/Sc (unlikely) (STAR 2014)
- W/ScFi + Fe/Sc – optimization via MC (Z. Xu/M.Sergeeva)
- W/ScFi + Pb/Fe/Sc (if timing will work) – optimization via MC (Z.Xu/M.Sergeeva/A.Kiselev)

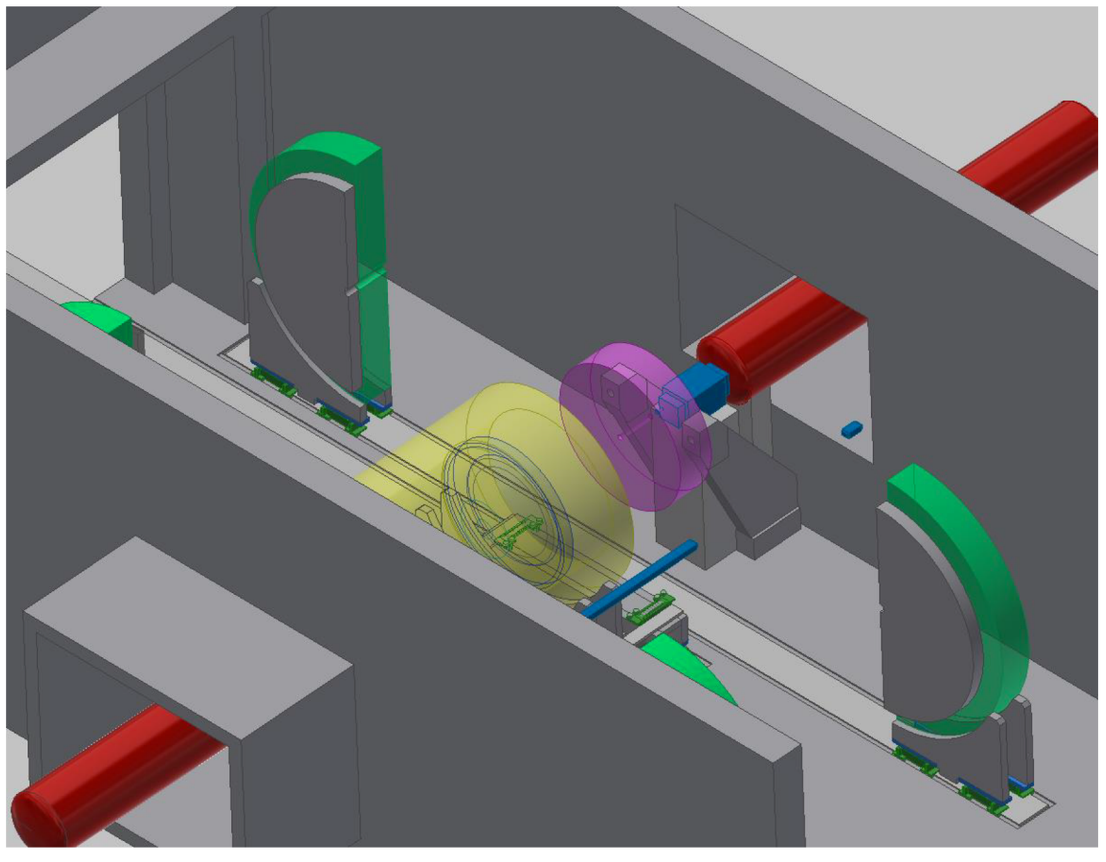
Had to consider: IR design, space constrain, integration issues, cost, time scale

e-RHIC IP6. Space is tight.



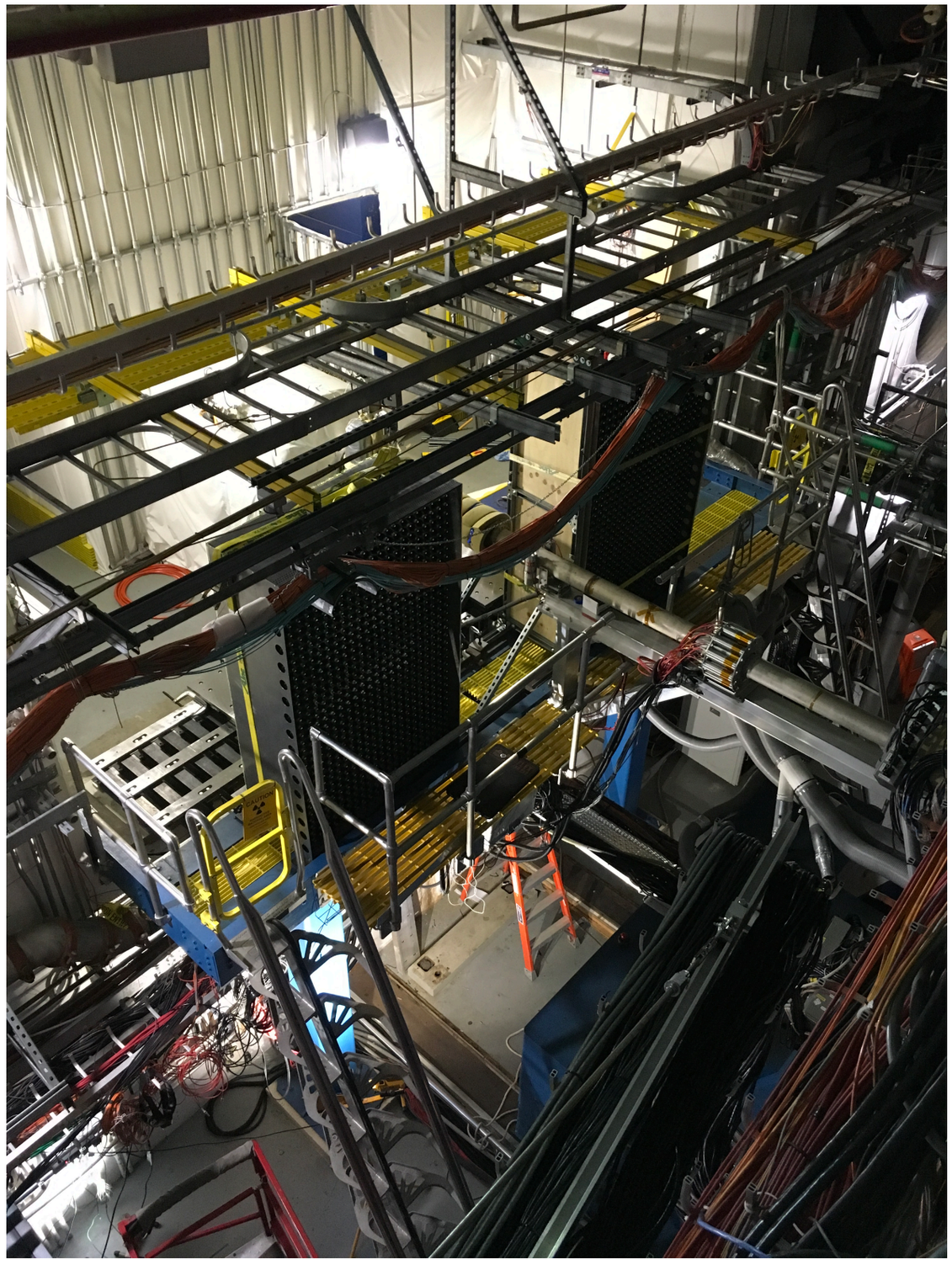






BNL group, (M. Baker, 3D drawings)

- IP6, STAR Forward Calorimeter System, Run 22.
- ~1/5 of a size of EIC Hadron Endcap



- Similar constrains to EIC central detector
- 500 GeV pp, conditions close to EIC high luminosity, SiPM readout.

FCS Current Status:

- EMCal, re-furbished PHENIX Shashlyk, modified for SiPM readout. 1500 Channels installed.
- New mechanical support structure for HCAL installed.
- About 10% of components for Hcal produced. Production facilities at different universities established.
- NSF Funds available on Sep. 1'st 2019. All major orders for the rest of the FCS were placed.
- First batches of components started to arrive.

Constrains as we see them and consequences:

1. Space very limited -> consequence - leakages
2. Time scale. CD0->CD2 -> consequence - no time to develop 'fancy' technology for Hcal.
3. Available EIC R&D funding (~ $30k/year) -> Build full scale prototype takes ~10 years
4. Overall Detector Cost.

- What are realistic numbers for energy resolution?
- What is absolutely needed?

Consensus after Yellow Report exercise?

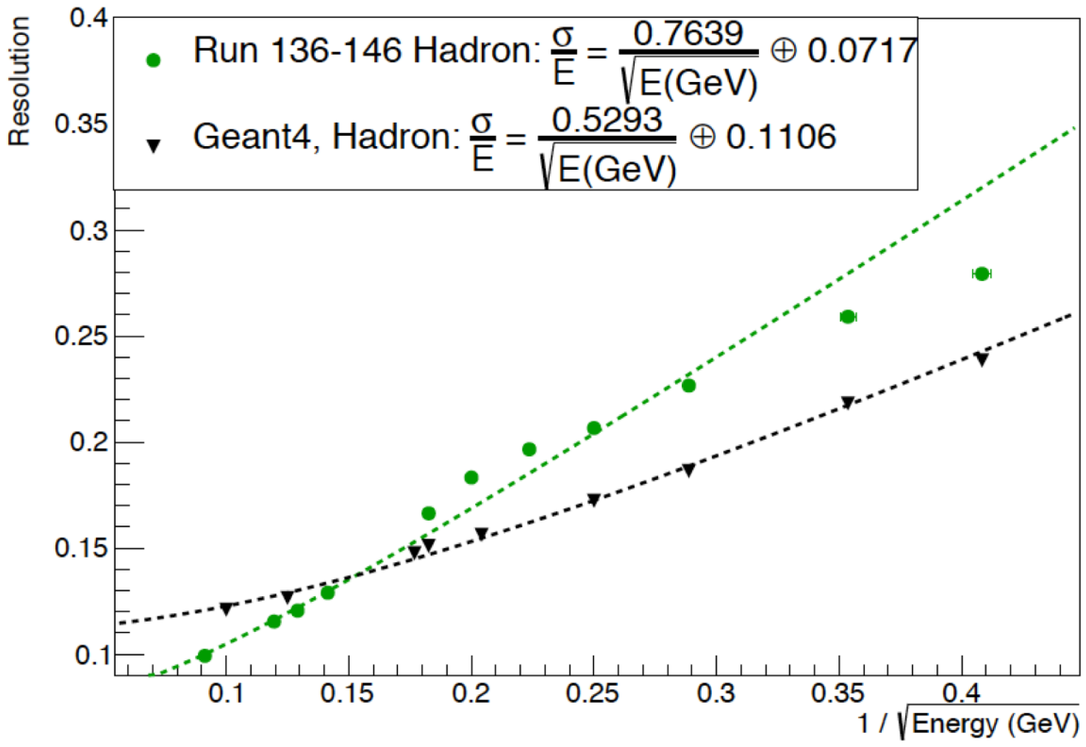
- 50%/√(E) + ? , as in the Detector HandBook - will require R&D, based on STAR FCS results.
- 40%/√(E) - unrealistic due to (1+2+3+4), IMHO

- Goal is to transition toward Targeted R&D.
- Targeted -> best possible configuration within constrains.

Optimal configuration is probably - W/ScFi (ECAL) + Fe/Sc (HCAL)

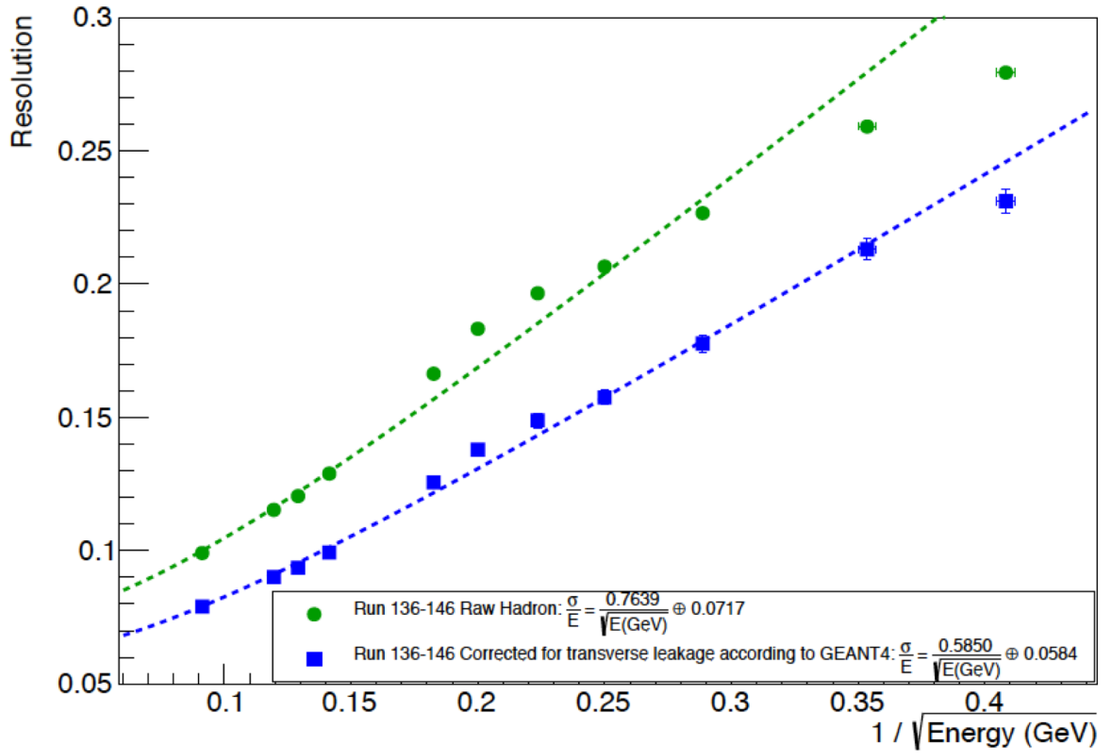
Path forward with re-aligned goals

1. Finish investigation of instrumental effects in connection with 2019 test beam results.
2. Optimization of W/ScFi+Fe/Sc system.



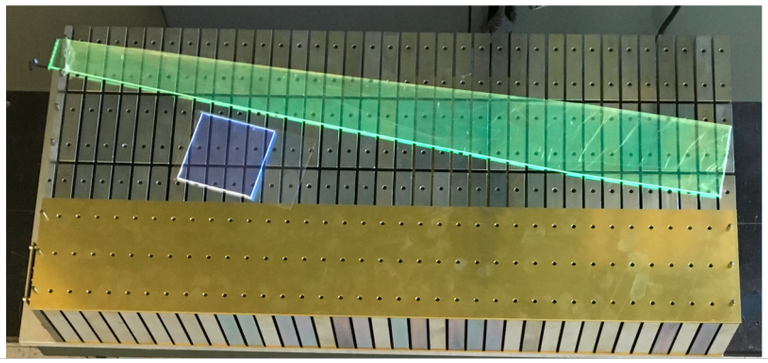
Why prototype underperformed?
Are we comparing apples to apples?

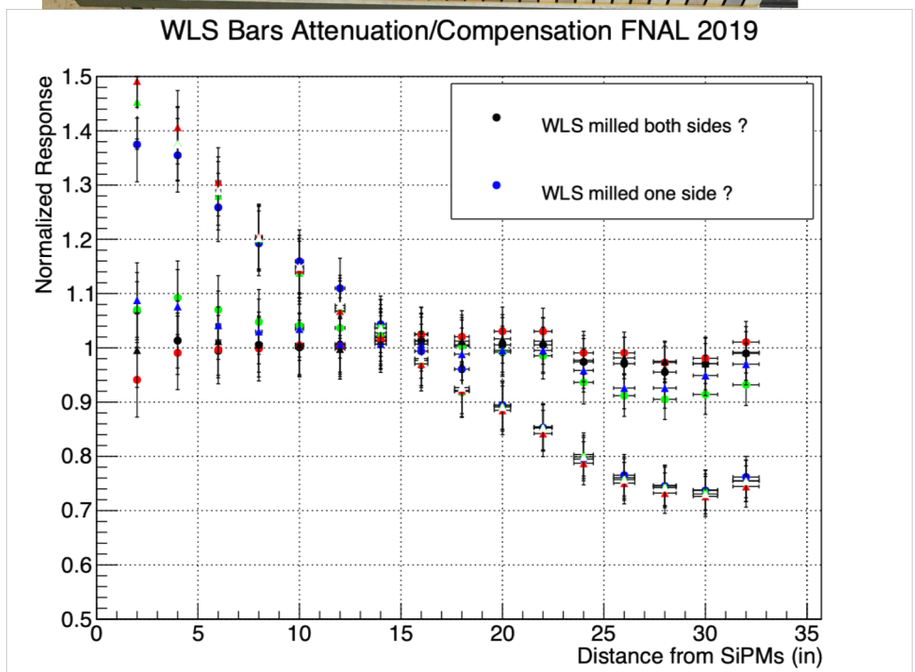
- Ideal vs detailed MC
- Instrumental effects (uniformities in light collection)

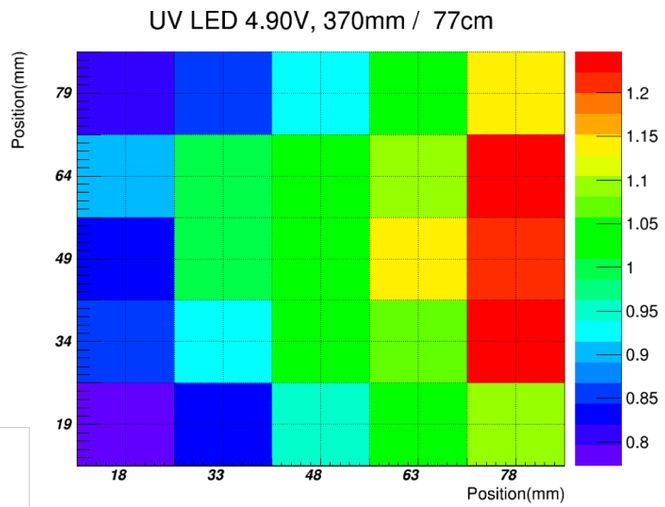


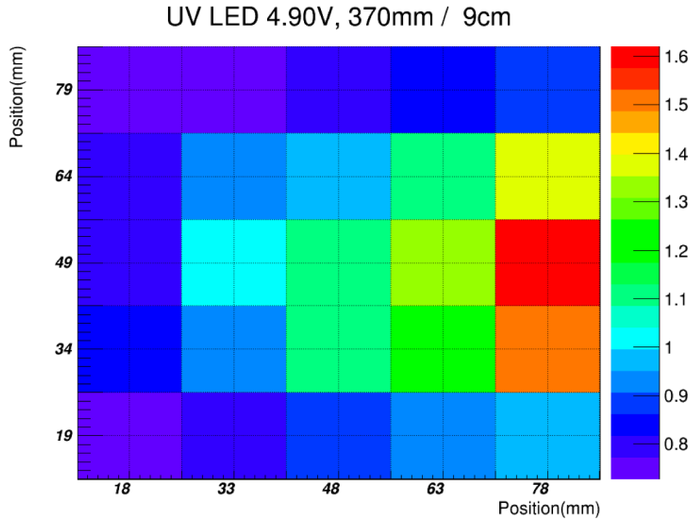
- Corrected for leakages, resolution in test run is close to 60%/√(E)⊕0.06.
- How much it can be improved?

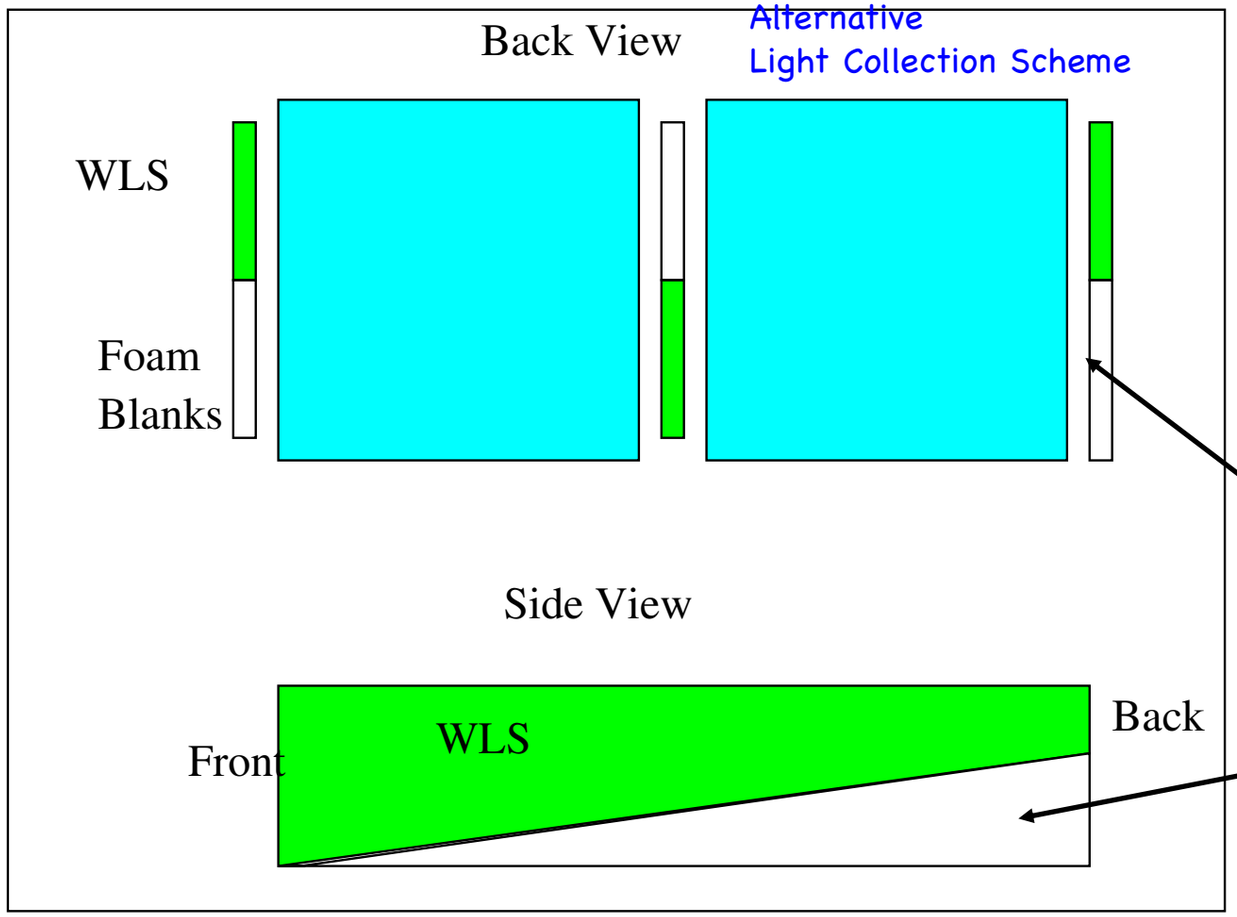
Instrumental effects. Transverse and Longitudinal non-uniformities in LY.





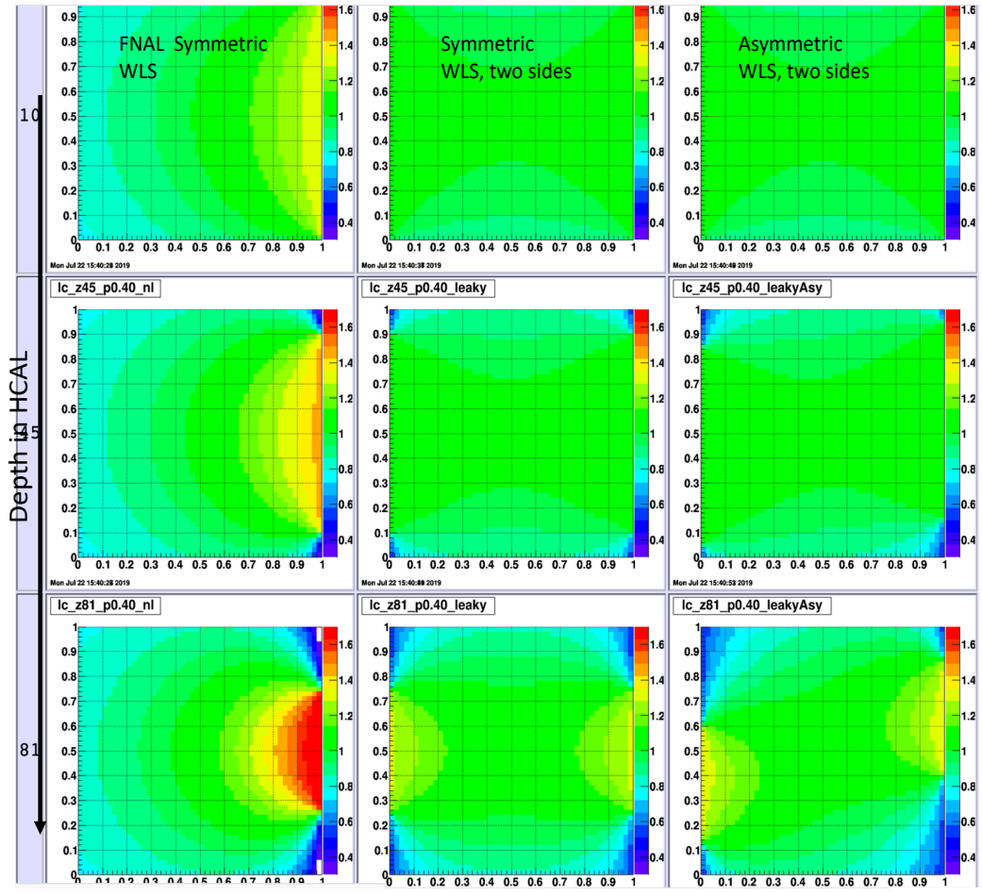






It was believed, that due to wide hadronic shower such large transverse non-uniformities will have little effect.

Longitudinal non-uniformities had very strong effect on energy resolution for Pb/Sc Hcal.



Tested three different schemes of light collection from Sc tiles.

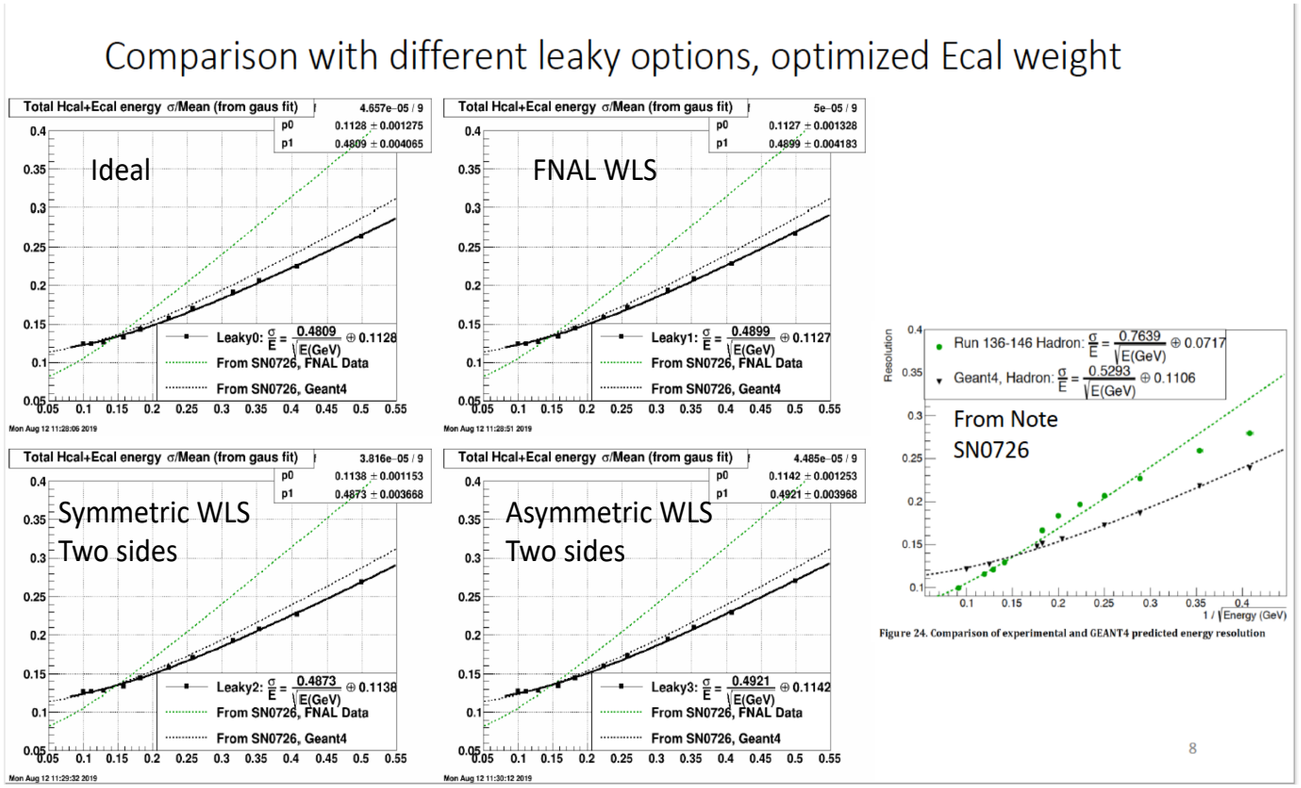
- Very little impact on resolution.
- GEANT3 (gSTAR, A.Ogawa (BNL) + T.Lin (TAMU)).

Effects of longitudinal non uniformities is under investigation.

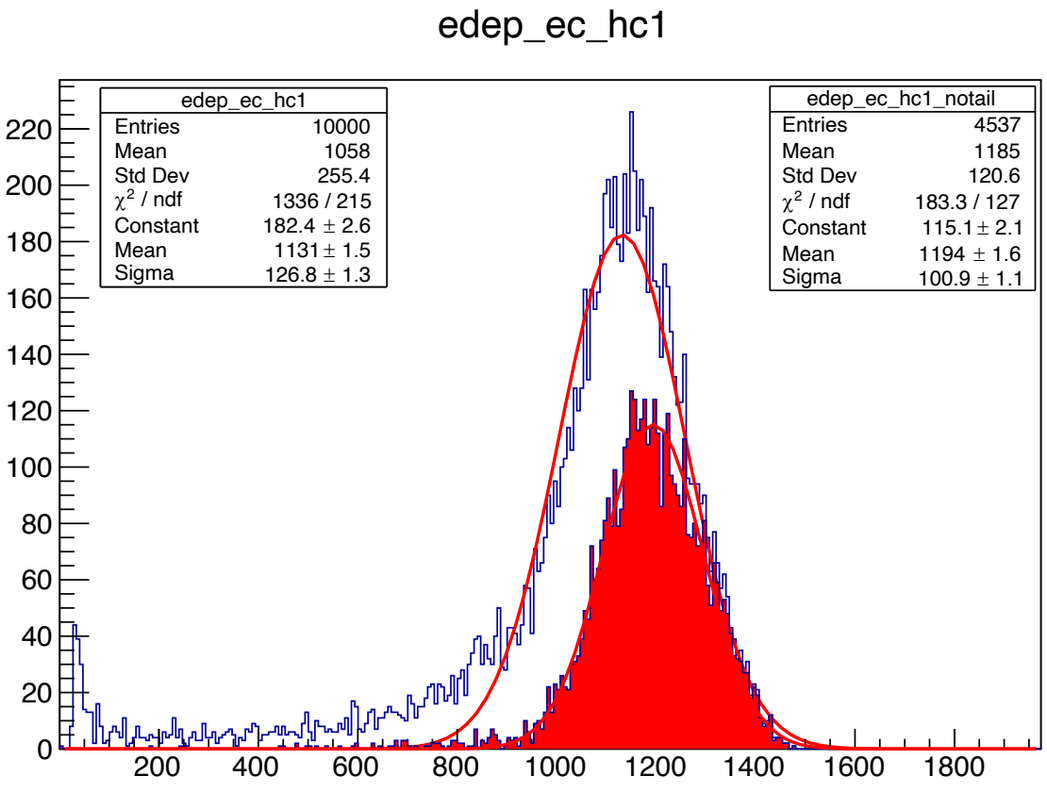
There are hints that some longitudinal non-uniformities actually helps with leaky system.

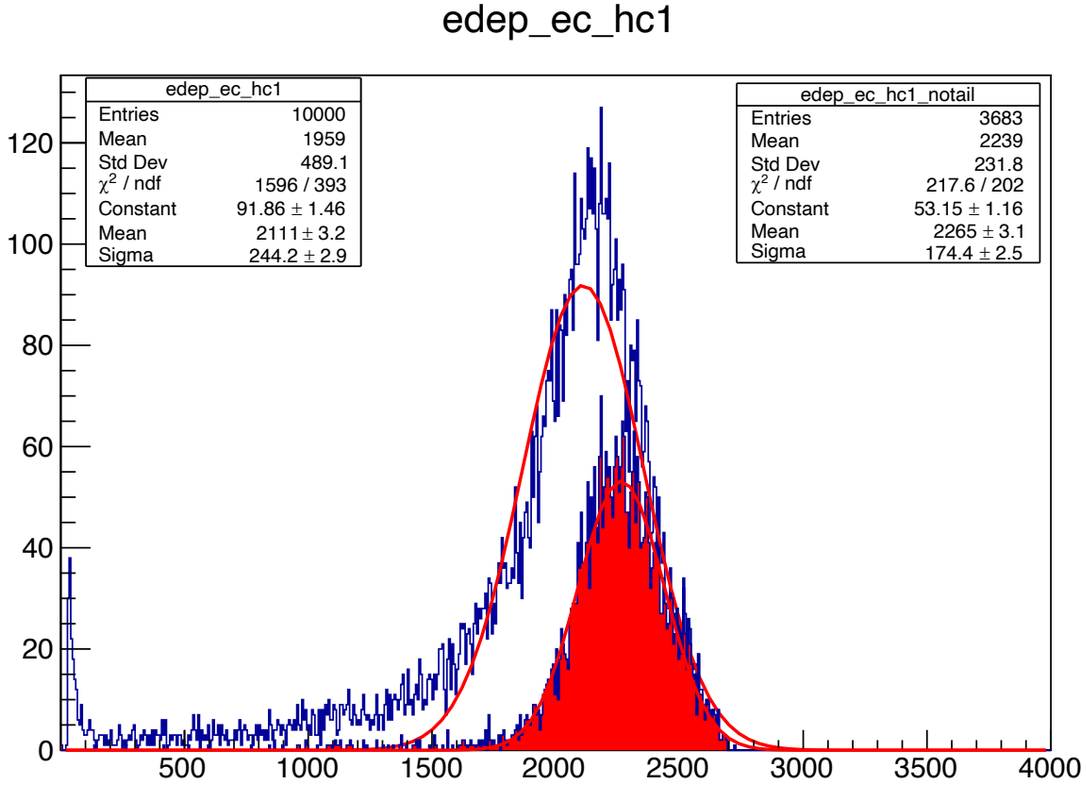
This study opened interesting direction for EIC hadron endcap system. Make it 4D.

We realized that with asymmetric WLS bars it will be relatively easy to implement longitudinally separated readout for Hcal (Full + tile catcher (~ 30%? of tiles at the back side) -> correct for leakages.



Tail Catcher. Example.





- Tail Catcher – last six sc. tiles in Hcal tower.
- For 6x6 cluster, E_{tail} < 2% E_{total}
- 64 Gev pi^-, efficiency ~50% improvements in energy resolution ~ 25%
- 120 GeV pi^-, efficiency 22%, improvements in energy resolution 50%

Questions:
How many tiles to sum, can additional improvements can be gained adding some Ecal information, spatial shower development etc…

Can resolution be improved by introducing some sort of correction based on tail-catcher information + other information in 4D system without throwing out events? ML?

Summary:

1. We are re-adjusting our goals toward targeted R&D. Conservative approach.
2. Synergy between STAR Forward and EIC R&D and now with UC EIC Consortia is important.
3. We will work very closely with BNL colleagues working on IP and central detector design.
4. MC machinery for optimizations and detailed timing simulation of shower development is being developed and partially in place at BNL (A.Kiselev), but it may not be needed. Timing is very tricky part and results from Test Run is not encouraging (signal from neutrons is very low, corrections for invisible energy in Fe/Sc structures not practical).
5. MC machinery for stand alone optimization is in place, supported by M.Sergeeva.
6. In next 6-12 months we want to advance optimization for Pb/Sc+Fe/Sc and W/ScFi+Fe/Sc (4D system).
7. W/ScFi+Fe/Sc is more expensive, but integration is easier and performance may be better.
8. There is an option for Hadron endcap with high resolution hcal insert (small angles) and associated R&D program (W/ScFi blocks + timing, resolution at ~ 30%/sqrt(E)). This has not been thought through in details yet.
9. Longer Term goals. ML, Full scale prototype.

Assuming current Detector HandBook numbers.

1 How much time do you envision to complete your ongoing project(s)

Optimization of Hadron EndCap 6-12 months. MC + some lab tests.

2 What achievements are required for TDR readiness 2023

1. Build and operate STAR FCS in Run 22.
2. Digest FNAL 2019 results, effect of different instrumental effects on performance.
3. Test optimized full scale prototype at FNAL early 2023, possible with appropriate funding.

Thanks!